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Illumination Distribution Measurements from Surface Sources in Sidewalls

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When illumination is obtained from luminous panels in the sidewalls of a room, from 44 to 73 per cent of the total area of the horizontal working plane receives less than average illumination, and the minimum illumination may range at least from 13 to 75 per cent of the average illumination. Such being the case, the usual flux-of-light method of design, based on utilization coefficients, is hardly permissible without important modifications, because it regards only the average illumination. Data on uniformity of illumination as well as on utilization coefficients, based on measurements made by means of an automatic recording photo-cell photometer operating in small-scale models of rooms, are given for various arrangements of luminous panels in the sidewalls, showing at least what are the most important precautions to observe if uniformity of lighting is to be approached. It is suggested further that minimum rather than average illumination be designed for, that the ratio of this minimum to the lumens admitted per square foot of floor area is perhaps a better guide than the utilization coefficient, and that more work be done to investigate the relation of this new factor to the conditions which affect it.

THE "Flux of Light" method[1] for calculating illumination, which on account of its simplicity and convenience is used in designing the great majority of lighting installations where any calculations at all are made, considers only one illumination for the entire working plane, the average value. There is plenty of experience[2, 3] to show, however, that in many cases it is not sufficient to know merely the average illumination, because the variations from point to point are large and because large portions of the working plane may have illumination much less than the average. By exercising intelligent

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control over the selection and placement of the light sources it is easily possible when desired, to make the illumination nearly enough uniform to deceive an eye unaided by photometer. Such knowledge as has been painstakingly gathered concerning relation of illumination to acuity and speed of vision and to nervous stress and fatigue should, however, make us desire to reduce as far as practicable the variations of illumination from point to point when work of the same kind is likely to be done anywhere in the lighted space.

The "Flux of Light" method of calculation, involving use of a "coefficient of utilization" or overall efficiency of the whole lighting system, really gives us no accurate idea of the illumination at any particular point. This failure becomes extremely important when the light sources are located in the sidewalls or near the horizon, instead of being distributed uniformly in the ceiling or over the floor or the room. Lighting experts have long recognized these excessively wide variations of illumination from point to point in a room whose light sources are in the sidewalls, as a serious difficulty in the natural lighting of multi-story buildings where glazed openings in the roof or ceiling could not be depended upon to equalize the illumination over all portions of the working plane. Notwithstanding this, architects in the last few years have been designing artificial lighting systems that involve luminous expanses of various shapes and locations in the sidewalls, deriving their brightness from incandescent filament lamps more or less hidden from direct view. Insofar as these arrangements are a substitute for the sidewall luminaires with unshielded clear or merely frosted lamps that were favored a few years ago, this development is an advance, even though large expanses of brightness not exceeding that of a north sky may be somewhat glaring and undesirable when they extend to within a few degrees from the horizon and when the eye is constrained to look toward them for long periods of time.

This investigation and paper is confined to consideration of distribution and efficiency of illumination in systems, either artificial or natural, which utilize rectangular expanses of approximately uniform brightness in the sidewalls, emitting their light in a diffuse manner or with approximately the same brightness when viewed in any direction. Two papers recently published[4, 5] contain the only other data for design of such systems with which we are acquainted, but neither of these gives any information as to the distribution of illumination which we consider so important in this type of lighting, with respect not only to horizontal but also to vertical working planes.

AUTOGRAPHIC LIGHTING SURVEY APPARATUS

Our first effort to predict the distribution as well as the average amount of illumination in a room lighted from luminous expanses, whose ceilings and walls contribute materially to the illumination by means of interreflections, was analytical: we tried to devise rational formulae for calculation of illumination at particular points on particular working planes, using mathematical methods that had previously proved successful[6,7] in predicting the direct component of illumination from surface sources of light. But it soon appeared that in such cases, the mathematical method, to be sufficiently accurate, would require more time and effort than an experimental method; and that even an experimental method, to handle the great variety of lighting systems favored by architects apparently on the basis of their interest from a decorative point of view, must enable us to procure the necessary technical data on any given design at much less cost than ever before in order to induce use of knowledge rather than guesses, and to depend for satisfaction upon good performance rather than upon mere appearance. One of us thereupon conceived, designed and perfected an autographic apparatus for making lighting surveys in scaled models of buildings, which is described elsewhere in detail.[8] While this apparatus can be used with any type and arrangement of light sources and room which can be reproduced accurately in small size (corresponding to a floor plan up to four feet square and a ceiling height up to two feet in the model), we have applied it so far only to the investigation of systems using luminous panels in the sidewalls because it is in that respect, we believe, most inadvisable developments are being undertaken. We hope to publish additional data later on these and other modes of lighting, procured by use of this apparatus and modifications.

The general set-up is illustrated by Fig. 1, a line drawing[9] because of difficulty in taking a comprehensive photograph in the small space available.

An adjustable angle-iron framework four feet square and two feet high can be made into a model room of any proportions within those limits, by means of removable plates of sheet iron arranged to permit us to adjust the size and location of openings in the sidewalls (and ceiling if desired) for admission of light from the uniformly bright surface of "light boxes." One of these "light boxes" is shown sending light into the model room (which occupies the middle ground of the picture) through openings in its rear wall. The light box was so

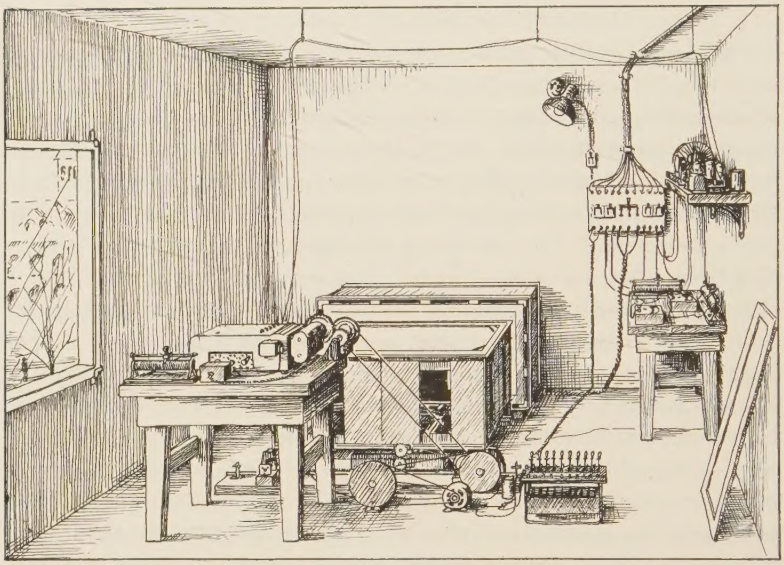

FIG. 1—Complete view of autographic illumination survey apparatus, comprising adjustable room and luminous surface, photoelectric photometer with amplifier, and electrical oscillograph for making photographic record of curves representing distribution of illumination.

carefully designed and constructed that the brightness of its surface within the region covered by openings in the model room seemed sensibly uniform, as the target of a Weston Illumination Meter was moved over it.

Through an opening in the near wall of the room can be seen a photoelectric cell in a small rectangular housing mounted on a track laid normal to the near and far walls. One (top) side of this housing is a piece of depolished diffusing glass toward which the light-sensitive surface of the cell faces; this is the working plane on which illumination is measured, and the housing can be adjusted so that it is horizontal or vertical facing any one of the four sidewalls. This track is itself mounted on other tracks parallel to the near and far walls. By means of suitable gearing to a motor, the "electric eye" is caused to move along a line parallel to the far wall and 1.5 inches from it, then on reaching the sidewall to move to another parallel line three inches farther from the far wall and along it to the other sidewall, then to and along another line three inches farther away from the far wall, and so on until the room has been completely covered, by perhaps as many as sixteen traverses. The near wall may be set at various distances

less than four feet from the far wall, and the ceiling can be lowered to any desired distance from the working plane or test-plate of the photocell, thus changing the proportions of the room in a way to correspond to quite wide ranges of the "Room Index." The ceiling and the walls may of course be readily repainted for any reflection factor.

Although the amount of current generated in the photocell corresponds exactly to the amount of illumination or surface density of light falling upon its test plate, this current is too small to actuate directly a recording device. An especially-designed amplifier, mounted on a shelf at the right, amplifies these currents to a value sufficient to give good deflections on an electrical oscillograph shown on the table at the left. In it, the lateral movement of a concentrated light-beam is proportioned to the illumination on the photocell test-plate. This beam falls upon a strip of photographic paper ("Insurance Bromide" in rolls of 100 feet, 5 inches wide), which by suitable gearing is given a longitudinal motion proportional to the motion of the photocell. The final result, that appears when the paper has been developed, is a curved line in which the distances (ordinates) of points measured from the reference line (corresponding to zero light on the photocell) are proportional to foot-candles on the test-plate, and distances along the reference line are indicative of the position of the cell with reference to the sidewall of the model room.

To determine the scale according to which the ordinates are to be translated into foot-candles, a special calibrating device is used which amounts to a photometer bar, with suitable screens against stray light, mounted at right angles to one of the light openings in the far wall. The photocell is held at various convenient distances along this bar, corresponding to its normal lines of movement, and the light densities on its test-plate are measured by means of a Macbeth Illuminometer. Comparison of these values with the corresponding heights of the photographically recorded line establishes the foot-candle scale.

Such calibration cannot be more accurate than the readings of an experienced photometrist on a Macbeth Illuminometer, but such degree of precision was considered to be quite sufficient for our purposes. To minimize the time devoted to calibrations, a small black box similar to the standardizing device of the Macbeth Illuminometer was constructed, containing a comparison-standard lamp held at a fixed distance from the test-plate and excluding all other light. With this device set upon the photocell test-plate before each survey, and after adjusting the voltage on both the standardizing device and the lamps

in the light-box to a predetermined constant value by aid of a calibrated voltmeter, the amplifier is adjusted so as to get the same deflection of the light beam of the oscillograph as in previous calibrations, and then the "Run" proceeds by starting the driving motor. The gearing is such that the maximum deflection is four to five inches, and the line is sufficiently sharp to permit measurements to within perhaps .02 inch. If the maximum reading were 4 inches this error should be quite insignificant, but if in the same oscillogram the minimum were only 0.1 inch as it might be when using sidewall lighting, the error might be a considerable percentage. We are trying to improve our technique in such respects as our experience grows with use of this new equipment.

Both ends of each traverse of the room are denoted by jogs in a straight line at one edge of the record strip, made by another element of the oscillograph actuated by an electrical current through contacts made between the photocell and stops at each end of its line of travel. Our present gearing is such as to make about 9 inches of record for each traverse of four feet, and a complete survey of sixteen traverses requires about five or six minutes of time, the photographic development another fifteen minutes perhaps. Then a template, prepared on transparent film from the original calibration, is applied to the oscillogram. This template has horizontal lines indicating values of illumination, and vertical lines marking the division of the working plane into squares three inches on each side, corresponding to a division of the total floor plan into 256 equal rectangles. Having applied this template to each section of the record in proper relation to the ends of the traverse, the reader estimates as closely as possible the mean ordinate of the curve between the limits of each square, and records it on a suitable form. The arithmetical mean of these ordinates is reasonably assumed to represent the average illumination in the room.

When the room is square, and the lighting arrangements are to be symmetrical on the four sidewalls, it should be sufficient to make the survey with only one sidewall lighted, and to assemble the observations properly. For this purpose, openings in the other three walls symmetrical with those which are rendered luminous by the light-box just outside one sidewall are covered by the same paper with which the light-box is faced, in order to take properly into account the interreflections. When the room is not square, the results of two surveys

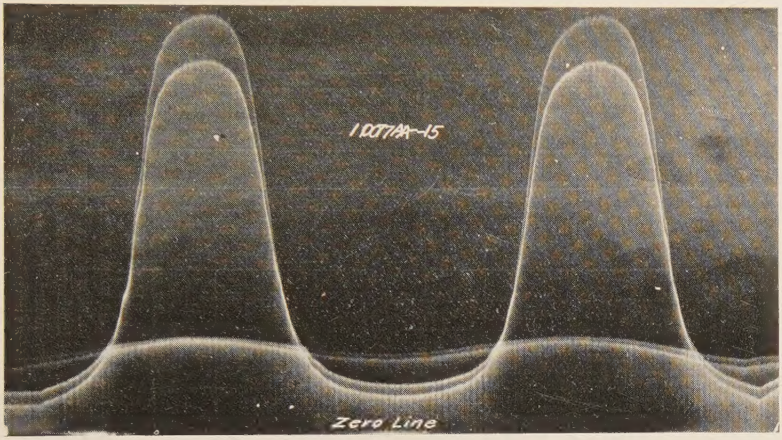

FIG. 2—Two autographic records superimposed, representing distribution of illumination on horizontal plane due to two luminous panels in one sidewall of a room. The curve with higher maxima and lower minima represents a traverse of the room at a distance from the panels equal to 0.086 times their height above the working plane; the curve with lower maxima and higher minima is for a line of stations distant from the panels 0.77 times the distance between working plane and top of panels.

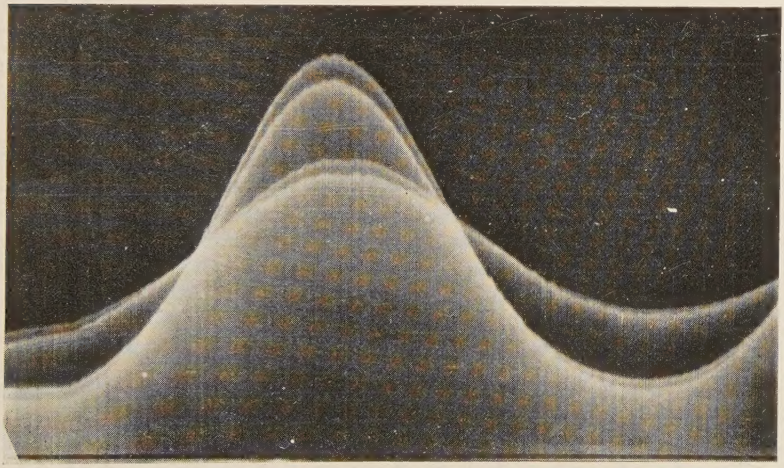

FIG. 3—Two superimposed records from the autographic recorder, one of which represents illumination on horizontal plane and the other on a vertical plane (facing luminous panels in sidewall), at a distance 0.43 times the distance between working plane and top of luminous panels. The illumination on vertical plane has higher maxima and lower minima than illumination on horizontal plane.

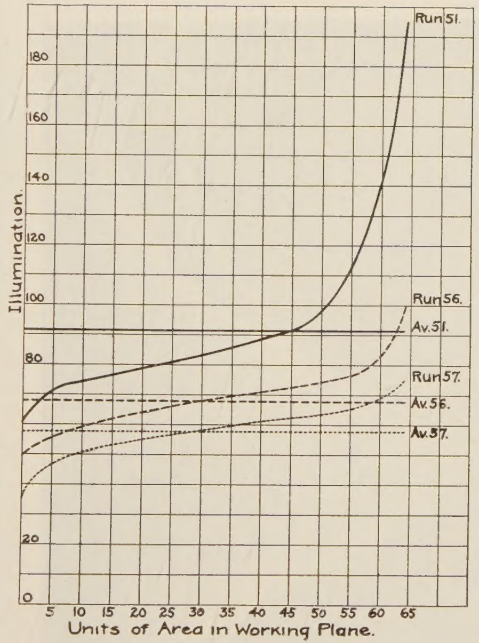

FIG. 4

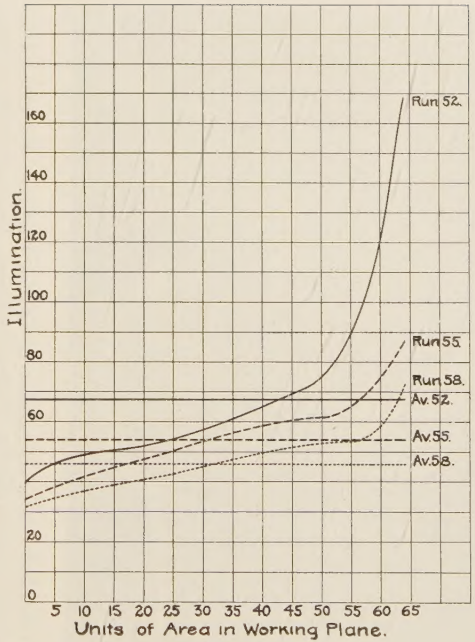

FIG. 5

FIG. 4.—Showing that a large part of the room has illumination much less than the average for the whole room, when lighting is from luminous panels in sidewalls. Conditions of Runs 51, 56, 57 differ only with respect to distance from working plane to lower edge of luminous panels: see Table I. "Room Index" approximately 2.0. For a given distance from working plane to ceiling and top of luminous panels, the illumination becomes generally less as the lower edge of luminous panels becomes higher, because with unvarying brightness a less amount of light is admitted into the room.

FIG. 5.—The ceiling height, and distance from working plane to top of luminous panels in sidewalls, is five units less here than in Fig. 4, for a room of the same number of units length and breadth. "Room Index" here is approximately 3.0. See Table I for data.

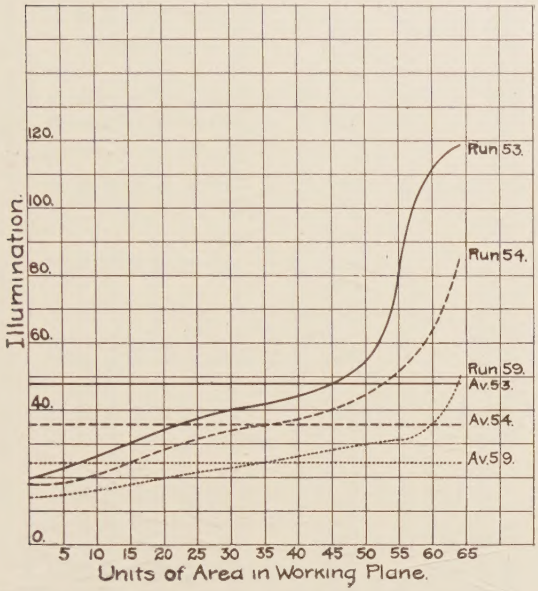

FIG. 6—The ceiling is lower than in Figs. 4 and 5 for the same length and width of room, in effect making the room larger and correspondingly increasing the "Room Index" to 5.0 or more. See Table I for data.

are combined, one with luminous panels in the longer sidewall and the other with luminous panels in the shorter wall.

RESULTS OF CHANGING HEIGHT OF CEILING, AND OF LOWER EDGE OF LUMINOUS PANELS

The effect of changing the height of the lower edge of the luminous panels above the working plane, for each of several values of ceiling height in relation to size of room, is illustrated by Figs. 4, 5 and 6 prepared from the data on Runs 51 to 59. The net results are summarized in Table I. From Figs. 4, 5, 6 it should be apparent that illumination from sources in sidewalls cannot be designed on the basis of average illumination only, as is done when the ordinary "Flux of Light Method" is employed, because a large part of the working plane (44 to 73 per cent under the conditions existing in these tests) receives considerably less than average illumination (as little as 42 to 74 per cent of average, in this series of tests). It should be remembered that the "minimum" meant here is not the illumination at a particular point where it may be unlikely that work is to be done, but is rather the mean illumination over a square having 1/256 part of the

TABLE I—Distribution of Illumination, and Utilization Coefficient, Due to Luminous Panels at Various Heights in Side-walls Only, of Square Rooms with Various Ceiling Heights

In these tests there were four panels in each of four walls, which were black.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Run No.	C.H.	S.H.	P.A.	F.P.	R.F.C.	R.F.W.	$\frac{\text{Min. E}}{\text{Av. E}}$	$\frac{\text{Av. E}}{\text{Max. E}}$	U.C.	$\frac{\text{Min. E}}{\text{Av. E}} \times \text{U.C.}$	B.P.	W.P.	Loc. Min.	Loc. Max.	L.T.A.
51	17.5	0.0	4$\frac{4}{4}$x4	48x48	0.65	0.05	0.68	0.51	0.34	0.23	177	H	1-H	1-B	0.73
52	12.5	0.0	4$\frac{4}{4}$x4	48x48	0.65	0.05	0.59	0.43	0.35	0.21	177	H	8-H	1-B	0.64
53	7.5	0.0	4$\frac{4}{4}$x4	48x48	0.65	0.05	0.42	0.41	0.41	0.17	177	H	8-H	1-B	0.70
54	7.5	2.0	4$\frac{4}{4}$x4	48x48	0.65	0.05	0.50	0.47	0.42	0.21	177	H	8-H	2-B	0.58
55	12.5	2.0	4$\frac{4}{4}$x4	48x48	0.65	0.05	0.63	0.64	0.33	0.21	177	H	8-H	2-B	0.48
56	17.5	2.0	4$\frac{4}{4}$x4	48x48	0.65	0.05	0.74	0.70	0.28	0.21	177	H	1-H	2-B	0.44
57	17.5	4.0	4$\frac{4}{4}$x4	48x48	0.65	0.05	0.63	0.78	0.28	0.17	177	H	1-A	3-C	0.44
58	12.5	4.0	4$\frac{4}{4}$x4	48x48	0.65	0.05	0.70	0.66	0.35	0.24	177	H	8-H	2-B	0.48
59	7.5	4.0	4$\frac{4}{4}$x4	48x48	0.65	0.05	0.58	0.52	0.45	0.26	177	H	8-H	2-B	0.55

LEGEND FOR TABLES I, II AND III

C.H. = ceiling height, units (inches) above working plane, which itself is 2.5 units above black floor.

S.H. = sill height, or units distance from working plane to lower edge of luminous panels in sidewalls. Since all luminous panels extend to the ceiling, the panel height equals ceiling height minus sill height.

P.A. = panel arrangement: thus, 4̲4̲4x4 indicates that the sequence of 4 units opaque wall, 4 units luminous panel and 4 units opaque wall is repeated four times in each of the four sidewalls.

F.P. = floor plan: thus 48x48 means 48 units (inches) square.

R.F.C. = reflection factor of ceiling.

R.F.W. = reflection factor of walls (not including translucent faces of panels, which have refl. factor 0.70).

$\frac{\text{Min. E}}{\text{Av. E.}}$ = ratio of minimum to average illumination, the minimum being not the value at the lowest point but the lowest average over a square three units on each side, and av. E being taken over the whole floor plan.

$\frac{\text{Av.E}}{\text{Max.E}}$ = ratio of average illumination over whole working plane, to greatest mean illumination over a square three units on each side.

U.C. = utilization coefficient or ratio, product av. E times floor area to total quantity of light emitted by luminous panels. Note that the total efficiency of the lighting system, or ratio of light flux on working plane to light flux emitted by lamps, should be obtained by multiplying this U.C. by the efficiency of the luminaires (or ratio of light flux output from panels to light flux generated by lamps).

B.P. = brightness of panels, in candlepower per square foot equals foot-candles, or lumens per square foot, received upon translucent test plate of Macbeth Illuminometer in contact with luminous panel, divided by π.

W.P. = slope of working plane: H meaning horizontal, V vertical and parallel to sidewall.

Loc. Min. = location of unit square having minimum illumination. Numbers denote lines of photocell travel parallel to walls, letters denote distance of unit square from adjacent sidewall. Thus, 1-H means the eighth square on the first row adjacent to one sidewall and 3-C represents the third square on the third row.

Loc. Max. = location of unit square having greatest mean illumination.

L.T.A. = fraction of floor area receiving less than-average illumination. Calculated directly from data, this figure may be slightly different from that shown by the curves of Figs. 7, 8 which were drawn smooth instead of stepped.

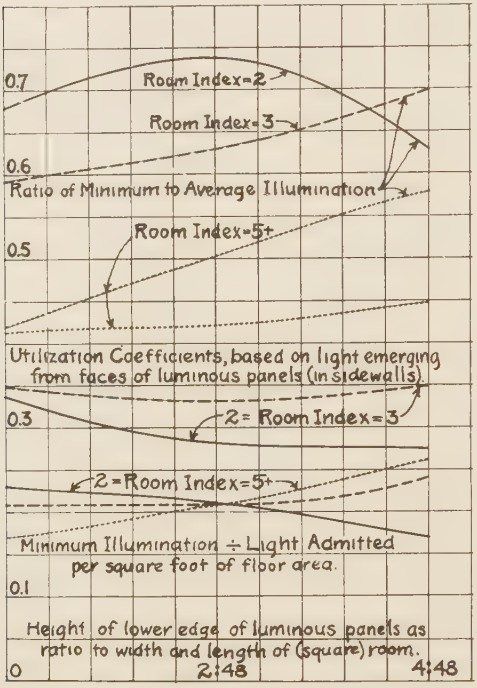

FIG. 7—Increasing height of lower edge of luminous panels in sidewalls above working plane appears to have comparatively slight effect on the utilization coefficient, at least within the limits of our tests so far; but the ratio of minimum to average illumination may be affected considerably, and there may be a particular height which gives optimum value to this ratio.

total floor area, or a three-foot square in a room forty-eight feet square. The minimum may occur at one corner of the room or the center of the room, or close to the middle of one sidewall, depending upon circumstances.

Under such conditions it seems that the lighting should be designed to produce a certain minimum rather than a certain average illumination. If a considerable number of people are compelled by the conditions of their employment to occupy steadily positions at desks or benches where the illumination is only fifty to sixty per cent of that which is proper for their work, it is small compensation for them to be assured that the average illumination over the entire room is adequate. The ratio of minimum to average illumination apparently varies over too wide a range to permit us to use a design based on the average, with a constant correction factor to take account of this ratio; so that if the "flux of light" method is to be retained on account of its con-

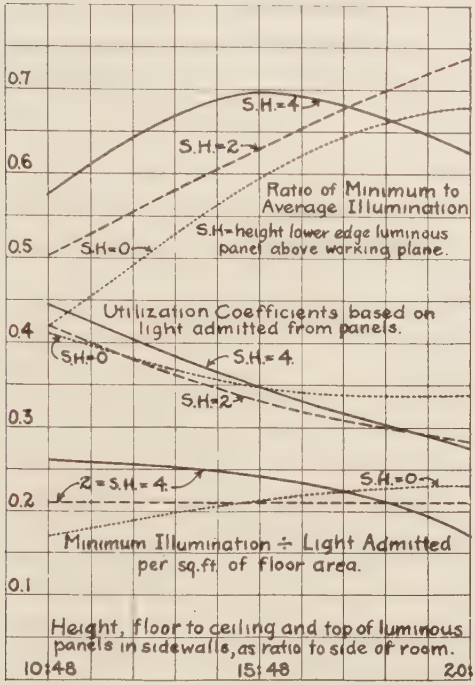

FIG. 8—Increasing distance from working plane to top of luminous panels in sidewalls, or increasing height of room and decreasing "Room Index," causes a quite considerable decrease in utilization coefficient but at the same time a corresponding increase in ratio of minimum to average illumination. There may be a particular ceiling height or "Room Index," at least with high luminous panels, which gives an optimum value to this ratio.

venience some new table of factors must be devised to take account of all the conditions which affect this ratio. The time available between the completion of our apparatus and the required closing date for this paper has not permitted us to explore adequately the effect of all such conditions, but we feel that a good start has been made. Apparently we have not yet used enough values of any variable to permit us to draw curves from which we can interpolate with confidence. From Figs. 7 and 8, where an attempt has been made to do this, it appears that changes which decrease the utilization coefficient increase the ratio of minimum to average illumination, although not in all cases. This, however, suggests that the product of ratios (min. E: average E) and (average E times area working plane: light flux admitted to room) might be useful in design. Such a product appears in column (11) of Table I; it is the ratio of minimum illumination to total light flux

admitted per unit floor area of the room, and it varies only from 0.17 to 0.26, relatively much less of a variation under the conditions of Runs 51 to 59 than that of the ratio min. E: average E. However, even here there appears to be enough variation to require use of another table of factors depending upon circumstances, at least when the lighting is from luminous panels in sidewalls. Perhaps it is indicated that rooms lighted from sidewalls should also have other luminous panels suitably disposed in the ceiling to bring up the minima and make the illumination more nearly uniform.

It is interesting to compare our results with those previously published,[4] as far as practicable which means with respect to utilization coefficient. Beggs and Woodside have reported some values of this coefficient for lighting from luminous panels in sidewalls, based we understand on tests of panel elements of relatively small size supplemented by calculations to take account of inter-reflections of light between the bounding surfaces of the room. With Room Index 2.0, reflection factors 0.50 for ceiling and 0.10 for walls, they give the utilization coefficient as 0.30 based on flux emitted by bare lamps, with luminous panels assumed to be emitting into the room 60 per cent of such flux. If their utilization coefficients had been based on flux emitted by the face of the panel, the corresponding figure should have been 0.30/0.6 or 0.50, which is quite considerably greater than the values 0.28 to 0.34 which result from our measurements (Runs 51, 56, 57, Table I) on a room having reflection factors 0.65 for ceiling and 0.05 (black) for the walls. With "Room Index" 3.0 (Runs 52, 55, 58), we find utilization coefficient ranging from 0.33 to 0.35 when reflection factors are 0.65 for ceiling and 0.05 for walls, while Beggs and Woodside find this coefficient to be 0.36/0.6 or 0.60 (extrapolated) with reflection factors 0.50 for ceiling and 0.10 for walls. The discrepancies between these results are far too large and indicate the need of further work. They may be due largely to differences between the conditions assumed by us and by them. Their results give no indication whatever of the changes in amount and distribution of light reaching the working plane, caused by variation in the number of luminous panels and their spacing around the sidewalls, as well as their distance from the working plane and the ceiling. Our data indicate, for the first time we believe, how important such factors may be. As further illustration of such effects, our data indicate that if in Runs 64–65 (Table III) only one luminous panel in the shorter side-

wall had been used instead of ten panels in four sidewalls, the utilization coefficient should be increased from 0.15 to 0.17.

RESULTS OF CHANGING REFLECTION FACTOR OF SIDEWALLS

All the results in Table I are based on four luminous panels each four units (inches) wide, distributed in each sidewall so that there is an opaque space of eight units between any two adjacent panels, the room being 48 units square and ten, fifteen or twenty units high from floor to ceiling. The luminous panels extend up to the ceiling in all cases, but down to various distances from the working plane, which itself is 2.5 units above the (black) floor. The reflection factor was 0.65 for the ceiling, 0.05 for the walls and 0.70 for the panel faces in all runs summarized in Table I. The conditions of the tests summarized in Table II differ from those of Table I only in that the reflection factor of the sidewalls between luminous panels was 0.30 (gray) instead of 0.05 (black).

The utilization factors in Table II are all higher than those of the corresponding runs in Table I, except in the case of Runs 51 and 151. They should be higher because the sidewalls reflect better. The exception is probably due to errors in Run 51. In our rush to complete runs in orderly series for the purposes of this paper we probably allowed insufficient time for our apparatus to attain constancy in the conditions of operation after starting up for the series of Runs 51 to 59, which affected the first run more than others of this series.

RESULTS OF CHANGING REFLECTION FACTOR OF CEILING, AND SHAPE OF ROOM

In Table III, Runs 60–61 and 64–65, in comparison with Run 51, indicate the effect of changing the width of the room, other things being equal. As should be expected, the utilization coefficient is greatly reduced by making the room narrower. Comparison of Runs 64–65 with Runs 62–63 gives some idea of the effect of higher or lower reflection factors for the ceiling, other things being equal. Run 157a is a repetition of Run 157 and should give the same results; the purpose is to give some idea regarding the dependability of our results. The differences in corresponding ratios are due to the fact that our measurements on the oscillograms showed a decrease of the minimum illumination from 46 to 44 foot-candles but with an increase of the maximum from 76 to 78 foot-candles, although the averages com-

TABLE II—Distribution of Illumination, and Utilization Coefficient, Due to Luminous Panels at Various Heights in Sidewalls Only, of Square Rooms with Various Ceiling Heights

Differs from Table I with respect to reflecting value of wall surface between panels.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Run No.	C.H	S H.	P.A.	F.P.	R.F.C.	R.F.W.	Min. E / Av. E	Av. E / Max. E	U.C	Min. E / Av. E × U.C.	B.P.	W.P.	Loc. Min.	Loc. Max.	L.T.A.
151	17.5	0.0	4 4 4 x 4	48x48	0.65	0.30	0.71	0.54	0.31	0.22	177	H	1-H	1-B	0.67
152	12.5	0.0	4 4 4 x 4	48x48	0.65	0.30	0.60	0.50	0.38	0.23	177	H	8-H	1-B	0.69
153	7.5	0.0	4 4 4 x 4	48x48	0.65	0.30	0.35	0.38	0.44	0.16	177	H	8-H	1-B	0.70
154	7.5	2.0	4 4 4 x 4	48x48	0.65	0.30	0.42	0.46	0.44	0.19	177	H	8-H	1-B	0.55
155	12.5	2.0	4 4 4 x 4	48x48	0.65	0.30	0.67	0.64	0.39	0.26	177	H	8-H	2-B	0.53
156	17.5	2.0	4 4 4 x 4	48x48	0.65	0.30	0.71	0.69	0.31	0.22	177	H	1-H	2-B	0.48
157	17.5	4.0	4 4 4 x 4	48x48	0 65	0.30	0.74	0.82	0 30	0.22	177	H	1-A	2-B	0 47
158	12.5	4.0	4 4 4 x 4	48x48	0.65	0.30	0.75	0 71	0.36	0 27	177	H	8-H	2-B	0 55
159	7.5	4.0	4 4 4 x 4	48x48	0.65	0.30	0.65	0.56	0.45	0.29	177	H	8-H	2-B	0.52

Note: See Legend accompanying Table I for explanation of column headings, etc.

TABLE III—Showing the Effects on Distribution and Amount of Illumination, of Changing the Shape or Proportions of a Room, the Reflecting Value of Walls and Ceiling, and the Distribution of Luminous Area, When the Room is Lighted from Luminous Panels in Sidewalls Only

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Run No.	C.H.	S.H.	P.A.	F.P.	R.F.C.	R.F.W.	$\frac{\text{Min. E}}{\text{Av. E}}$	$\frac{\text{Av. E}}{\text{Max. E}}$	U.C.	$\frac{\text{Min. E}}{\text{Av. E}} \times \text{U.C.}$	B.P.	W.P.	Loc. Min.	Loc. Max.	L.T.A.
51	17.5	0.0	4 4 4 x4	48x48	0.65	0.05	0.68	0.51	0.34	0.23	177	H	1-H	1-B	0.73
60	17.5	0.0	4 4 4 x2	24x48	0.65	0.05	0.64	0.60	0.22	0.14	177	H.	1-H	1-B	0.66
61			4 4 4 x4												
64	17.5	0.0	4 4 4 x1	12x48	0.65	0.05	0.65	0.71	0.15	0.10	177	H	1-A	1-G	0.56
65			4 4 4 x4												
62	17.5	0.0	4 4 4 x1	12x48	0.05	0.05	0.61	0.68	0.12	0.07	177	H	1-H	1-B	0.56
63			4 4 4 x4												
157	17.5	4.0	4 4 4 x4	48x48	0.65	0.30	0.74	0.82	0.30	0.22	177	H	1-A	2-B	0.47
157a	17.5	4.0	4 4 4 x4	48x48	0.65	0.30	0.70	0.81	0.30	0.21	177	H	1-A	2-B	0.53
1	17.5	0.0	8 8 8 x2	48x48	0.05	0.05	0.13	0.34	0.17	0.02	177	H	1-A	1-E	0.58
107	17.5	0.0	8 8 8 x2	48x48	0.85	0.68	0.56	0.47	0.36	0.20	177	H	1-A	1-D	0.66

Note: See legend accompanying Table I for explanation of column headings, etc.

pared as 62.4 to 62.9. Such discrepancies are probably due not so much to difficulty in reading accurately to the line of the oscillogram, as to the variation in our judgment of what is the mean ordinate over a certain range in the abscissa of the curve. Each such judgment was made in a few seconds, to save time.

The effect of changing the number and arrangement of the panels in the sidewall is barely indicated by Runs 1 and 107, wherein the same total luminous area is divided into half as many panels each twice as wide as before, and twice as far apart. This results in even greater non-uniformity of illumination, other things being equal. We have a large number of oscillograms for such cases but not sufficient time to measure them and prepare the results before going to press.

We do not present these results as being comprehensive and final, but we do believe that they are fully as accurate as any corresponding data obtained by visual photometer, and certainly they are much less costly to obtain. They open up, even if they do not adequately cover, a field in which data are meagre, and we think that they should be useful to designers of lighting from luminous panels in sidewalls. We shall continue our work when and as conditions permit.

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